Childhood Asthma and the Indoor Environment*

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To investigate the influence of indoor air quality on respiratory health, a questionnaire-based study of 17,962 Canadian schoolchildren in kindergarten through grade 2 was carried out in 1988. The present report focuses on associations between several indoor environmental factors and childhood asthma. Increased reports of physician-diagnosed asthma were significantly associated ($p<0.001$) with exposure to environmental tobacco smoke (OR = 1.4), living in a damp home (OR = 1.5), the use of gas for cooking (OR = 2.0) and the use of a humidifier (OR = 1.7). Wheezing without a diagnosis of asthma also was associated ($p<0.01$) with environmental tobacco smoke (OR = 1.4), home dampness (OR = 1.6) and humidifier use (OR = 1.4), but not with gas cooking. Thus, several modifiable risk factors for respiratory illness may exist in Canadian homes. Further research is required to determine the nature of these cross-sectional observations. *(Chest 1991; 100:922-26)*

CI = confidence interval; OR = odds ratio

Asthma, one of the most common respiratory diseases, affects about 5 percent of the general population and 7 to 10 percent of children.[1,2] Over the past 20 years, increases in asthma morbidity and mortality have been reported in several countries.[3-7] The reasons for this are not fully understood, but increased exposure to various indoor allergens may play a role.[8]

In industrialized countries, the majority of the people spend more than 90 percent of their time indoors,[9] and thus have long duration of exposure to the potentially harmful airborne contaminants commonly found indoors. This is especially true for countries such as Canada with long cold winters. Installing additional insulation for energy conservation has reduced air exchange rates and may have increased the concentrations of indoor pollutants.[10] Exposure to contaminants from gas cooking, environmental tobacco smoke and molds in the home may increase the risk of respiratory illness.[10-12]

This report focuses on the influence of the indoor environment on asthma in a population of Canadian schoolchildren. To avoid referral bias, such as may be found in clinical studies, we also studied children with persistent wheeze but without physician-diagnosed asthma. Without the label of asthma, they would perhaps be less likely to have been counselled by a physician and less likely to have modified their home environment.

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Subjects and Methods

Study Population and Survey Procedures

The data used in this study were obtained from the 1988 Canadian Air Quality and Health Study, a questionnaire-based study of respiratory health and the indoor home environment.

The questionnaire was developed from the 1978 American Thoracic Society—Division of Lung Disease questionnaire, the questionnaire used in the Harvard Six Cities study, the questionnaire used in the Canadian Community Child Health study and the Environmental Inventory Questionnaire.[11-13] It was administered between March and April 1988 in 30 communities spanning the East to West coasts of Canada. The communities, all without significant local industrial sources of air pollution, represented six regions with differing estimated exposures to sulfate air pollution. These regions were: Southwestern and Central Ontario which had relatively high sulfate exposure, Quebec and the Maritimes which had medium exposure, and Saskatchewan and British Columbia which had low exposure. The health effects of ambient air pollution will be presented elsewhere.

Schoolchildren (n = 17,962) attending kindergarten through grade 2 received the questionnaire at school; parents or guardians answered 14,948 of the questionnaires. For the purpose of this study only the 14,059 children between 5 and 8 years of age were included. Those with cystic fibrosis (n = 17) and those who lived in mobile homes, tents, vans, trailers and boats (n = 547) were excluded.

Of the remaining 13,495 children, 10,819 children were classified into the following three study groups:

1. Children with wheezing most days or nights, or wheezing apart from colds, or attacks of shortness of breath with wheezing, but without physician-diagnosed asthma (n = 978).
2. Children with current asthma whose parents answered yes to the questions, "Has a doctor ever said this child had asthma?" and "Does he or she still have asthma?" (n = 634).
3. A comparison group of children without persistent cough, wheezing, persistent phlegm, diagnosed asthma and who had no reported chest illness, pneumonia or bronchitis within the past year (n = 9,207).

The 2,676 remaining children did not fall into any of the above categories. These children would have reported any of the following: wheezing only with colds, previous but not current asthma, persist-

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Table 1—*Sociodemographic Characteristics of Children in Cohort**

Characteristics	Study Groups: Asymptomatic (n = 9,207)	Wheezing Syndrome (n = 978)	Current Asthma (n = 634)
Age (yr)			
5	19.3	21.8	18.8
6	31.7	33.0	29.0
7	33.4	30.4	38.2
8	15.6	14.8	14.0
Sex of child			
M	49.3	57.1†	62.9†
F	50.8	42.9	37.1
Race			
White	96.5	96.2	96.5
Other	3.5	3.8	3.5
Maximum parental education			
High	54.4	49.7†	53.6
Low	45.6	50.3	46.4
Sex of respondent			
M	17.8	14.1†	11.8†
F	82.2	85.9	88.2
Crowding (persons per room)			
≤0.75	70.8	72.0	76.0†
>0.75	29.2	28.0	24.0

*Values are expressed in percentages.
†Difference from asymptomatic group statistically significant at $p<0.01$.

ent cough or phlegm, recent chest illnesses, pneumonia or bronchitis.

Environmental tobacco smoke exposure was characterized by the number of household smokers. Home dampness and mold was defined as the presence of any one of the following: visible mold growth, wet or damp spots on indoor surfaces or basement water damage or leaking. Gas cooking was defined as the use of natural gas as the primary cooking fuel. Humidifier use was considered present if it was used at least three times weekly.

Covariables used to adjust the association between exposures and illness were the following: age, race, sex of child, highest level of education achieved by either parent (no post-secondary, at least some post-secondary), sex of respondent, region of residence and household crowding (persons per room).

Statistical Methods

Associations between exposures and health outcomes were assessed using chi-square tests of significance. The resulting OR with 95 percent confidence intervals were reported. To control for potential confounding factors, the OR were adjusted using multiple logistic regression and the maximum likelihood method, and the corresponding 95 percent confidence intervals were computed. The adjustor covariables were age, race, sex of child, parental education, sex of the respondent, region of residence, crowding, dampness, gas cooking and environmental tobacco smoke. The exposure variables (humidifier use, pets, heating fuels and heating systems) were each entered in the model separately. Prevalences of the environmental exposures and the covariables were reported for each of the three study groups. All statistical analyses were done using the Statistical Analysis System.[10]

Results

The prevalences of asthma and the wheezing syndrome were 4.7 and 7.2 percent, respectively. Age and race distributions were similar across all three study groups (Table 1). Prevalences of childhood asthma and wheezing were higher among boys and among children whose questionnaires were completed by a female respondent. Wheezing but not asthma was more common among families with lower education, whereas asthma but not wheezing was more common in non-crowded homes.

As shown in Table 2, smoking, gas stove use, home dampness and humidifier use were more common in the homes of wheezing and asthmatic children than in the homes of asymptomatic children ($p<0.05$). The presence of furry or feathered pets appeared to be more common in the homes of wheezing children ($p<0.05$) and least common in the homes of asthmatic children. Gas and oil were more commonly used as heating fuel and forced air as a heating system in the homes of the asthmatic children than in the homes of asymptomatic children ($p<0.05$).

Table 3 shows the crude and adjusted OR with 95 percent confidence intervals for various home environmental factors. Smoking in the home was significantly associated with both wheezing and asthma ($p<0.001$). A dose-response relationship was seen, that is, the OR were larger when two or more smokers were present in the home than when there was just one smoker. Home dampness and mold and the frequent use of a humidifier also were significantly associated with both wheezing and asthma ($p<0.01$). The crude associations observed for gas stove use persisted only for asthma after adjusting for the

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Table 2—*Prevalences of Indoor Environmental Factors in the Three Study Groups**

Indoor Exposure	Study Groups: Asymptomatic (n = 9,207)	Wheezing Syndrome (n = 978)	Current Asthma (n = 634)
No. of household smokers:			
0 smokers	49.8	38.3	39.3
1 smoker	27.7	29.5§	30.9§
>1 smoker	22.5	32.2§	29.9§
Gas cooking			
Present	4.8	6.5†	9.4§
Absent	95.2	93.5	90.6
Dampness			
Present	34.9	47.1§	46.3§
Absent	65.1	52.9	53.7
Use of humidifier			
Present	24.8	20.7§	34.8§
Absent	75.2	70.3	65.2
Furry or feathered pets			
Present	47.3	50.4	43.1
Absent	52.7	49.6	56.9
Type of heating fuel			
Gas	30.2	32.6†	36.6§
Oil	17.2	16.3	25.2§
Wood	13.8	13.3	8.3
Electricity	37.6	34.2	28.0
Other	1.2	1.6	1.9
Type of heating system			
Forced air	38.2	37.9	46.6‡
Baseboard heater	31.6	33.3	30.5
Wood stove	26.0	23.9	18.8
Other	4.2	5.0	4.1

*Values are expressed in percentages.
†$p<0.05$ (two-sided).
‡$p<0.01$ (two-sided).
§$p<0.001$ (two-sided).

Table 3—*Odds Ratios (95% Confidence Intervals) of Indoor Factors for Childhood Asthma or Wheezing Compared with Asymptomatic Children**

	Study Groups: Wheezing Syndrome		Current Asthma	
	Crude OR	Adjusted OR	Crude OR	Adjusted OR
Environmental tobacco smoke				
1 vs nonsmokers	1.39	1.39 (1.17, 1.65)†	1.42	1.40 (1.13, 1.73)†
>1 vs nonsmokers	1.86	1.72 (1.44, 2.05)‡	1.69	1.59 (1.28, 1.98)‡
Dampness	1.66	1.61 (1.39, 1.85)‡	1.61	1.46 (1.22, 1.74)‡
Gas cooking	1.37	1.04 (0.77, 1.42)	2.04	1.95 (1.41, 2.66)‡
Use of humidifier	1.28	1.35 (1.15, 1.59)‡	1.62	1.66 (1.36, 2.01)‡
Furry/feathered pets	1.14	1.04 (0.90, 1.21)	0.84	0.77 (0.65, 0.93)†
Type of heating fuel				
Gas-electricity	1.19	1.09 (0.85, 1.41)	1.63	1.33 (0.95, 1.87)
Oil-electricity	1.18	0.85 (0.65, 1.12)	1.98	1.35 (0.97, 1.87)
Wood-electricity	1.06	1.03 (0.80, 1.31)	0.81	0.76 (0.52, 1.10)
Type of heating system				
Forced air-electricity	0.94	0.84 (0.69, 1.03)	1.26	1.12 (0.86, 1.42)
Wood stove-electricity	0.87	0.89 (0.73, 1.07)	0.75	0.63 (0.64, 1.07)

*See statistical methods section in text for description of methods used.
†$p<0.05$ (two-sided).
‡$p<0.01$ (two-sided).
§$p<0.001$ (two-sided).

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covariables ($p<0.001$). The association between wheezing and gas cooking was influenced by region: the crude OR was significant only for Central Ontario, 2.1 (95 percent CI 1.0, 4.2). The OR for the other regions ranged from 0.66 to 1.64 but all CI included 1. The presence of furry or feathered pets was less prevalent in the homes of children with asthma ($p<0.05$) but not with wheezing. Crude associations observed between heating fuels and symptoms did not persist following adjustment. The individual OR for each of the aforementioned indoor exposures were relatively small (less than or equal to 2.04). This means that the odds of having the symptom when exposed to any individual risk factor are generally less than twice the odds of having the symptom when not exposed. The risks, however, were higher in the 1 percent of the subjects who were exposed to more than one risk factor. In particular, the OR for the association between asthma and exposure to tobacco smoke, dampness and mold and gas stoves together was 5.4 (95 percent CI 2.7, 9.5). The maximum proportions of asthma attributable to exposures, *ie*, attributable risks, were 0.22 for tobacco smoke, 0.19 for dampness and mold and 0.02 for gas stoves.

Discussion

The present large cross-sectional study indicated that gas cooking, exposure to environmental tobacco smoke, home dampness and humidifier use were associated with the prevalence of current asthma. The latter three exposures were associated with wheezing. The OR were generally less than 2 for individual exposures, suggesting effects that were not very large. Although the OR were low, a relatively high proportion of subjects were exposed, resulting in important attributable risks: approximately 20 percent for each of tobacco smoke, and home dampness and mold. Misclassification of exposure and outcome variables (measured crudely by questionnaires) could have reduced the observed OR.

Underdiagnosis and undertreatment of childhood asthma have been reported to occur.[17,18] A diagnosis of asthma requires a visit to the physician which could be influenced by the socioeconomic status of the family. Moreover, a visit to the physician does not guarantee a correct diagnosis. First, a physician has to recognize that the child has asthma and, second, there is evidence that physicians do not want to stigmatize a child with this diagnosis.[17,18] For these reasons we also looked at children with wheezing but without physician-diagnosed asthma. Another reason for looking at this group was that families with known asthmatic children may modify their home and thereby obscure relationships between asthma and the indoor environment. Our finding that pets were less likely to be present in homes of asthmatic children supports the hypothesis that independently or upon the advice of a physician, allergenic pets have been kept out of the home.

Our results are consistent with those of others[12,19-21] in showing that home dampness is associated with both current asthma and wheezing syndromes. However, the results do not allow identification of causal mechanisms. Home dampness reflects inadequate ventilation which may cause increased concentration of various contaminants. House dust mites and fungi are both known to be more prevalent in damp homes, and they are also both known to produce substances that may trigger allergic reactions;[10] Fungi may, in addition, produce mycotoxins causing adverse health effects,[10] but there is yet very little direct evidence showing that this mechanism is responsible for the observed associations between home dampness and respiratory disease.

Independent of reported home dampness and visible mold growth, humidifier use was associated with both wheezing and asthma. Possible explanations include air contamination by microorganisms colonizing wet surfaces or particles from the water supply. Alternatively, the presence of wheezing or asthma may have prompted parents to humidify the air hoping to relieve symptoms. Fielding and Phenow,[22] in a recent review, pointed out that some studies but not others have been able to detect adverse effects of environmental tobacco smoke exposure on asthma. Our results clearly support such an association. The OR was approximately 1.5, highly statistically significant at $p\leq0.001$, and a dose-response gradient was detected.

Gas cooking which emits nitrogen dioxide has variably been associated with increased respiratory symptoms.[11,23,24] We demonstrated statistically significant effects which persisted for current asthma but not wheezing following adjustment. This finding must be treated with caution, however, because of the few subjects with asthma in our study who were exposed ($n = 60$). It is possible that unmeasured characteristics of this particular group are in fact responsible for the observed association with gas cooking.

Apart from indoor pollutants, we found that the sex of the questionnaire respondent was related to the reporting of asthma and wheeze. Apparently, female respondents (usually the child's mother), were more aware of their children's symptoms than male responders. We therefore recommend that this potential confounder be taken into consideration when planning future studies.

Modifying the indoor environment is an important consideration in asthma management. Clinicians often emphasize dust control, removal of furry or feathered pets from the home, and more recently, avoidance of environmental tobacco smoke. We have found cross-sectional associations between several modifiable in-

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door exposures and respiratory illness. Considering the prevalence and morbidity attributed to asthma in our society, the influence of these exposures deserves further study.

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